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Holger Wiese, Stefan R. Schweinberger

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Inequality between biases in face memory: Event-related potentials reveal dissociable neural correlates of own-race and own-gender biases

Holger Wiese[1] & Stefan R. Schweinberger[2]

[1]*Department of Psychology, Durham University, United Kingdom*

[2]*Department of General Psychology, Friedrich Schiller University of Jena, Germany*

Corresponding author:

Dr Holger Wiese

Department of Psychology

Durham University

E009 Wolfson Building, Queen's Campus

Stockton-on-Tees, TS17 6BH

United Kingdom

Email: holger.wiese@durham.ac.uk

Phone: +44 191 3340433

Abstract

Humans are more accurate at remembering faces from their own relative to a different ethnic group (own-race bias). Moreover, better memory for faces from an observer's own relative to the other gender (own-gender bias) has also been reported, particularly for female participants. Theoretical explanations for these effects either emphasize differential perceptual expertise or socio-cognitive factors. Importantly, both types of explanations typically assume a single common mechanism for the various biases. The present study examined event-related potentials (ERP) in a combined own-race/own-gender bias experiment. Whereas both male and female participants demonstrated clear own-race biases in memory performance, enhanced memory for own-gender faces was only observed in female participants. Moreover, the own-race bias was accompanied by larger N170 responses for other-race faces, presumably reflecting more effortful perceptual processing of this face category. Neural correlates of the own-gender bias manifested at later processing stages, reflecting the processing of individual faces (N250) and recollection-based memory retrieval (late ERP old/new effect). We conclude that different face memory biases occur at temporally distinct stages of face processing and are therefore based on different mechanisms. This suggestion is at variance with the assumption of a single common mechanism to underlie the various biases in face memory.

Keywords: Face Recognition; Event-Related Potentials; N170; Own-Race Bias; Own-Gender Bias

1. Introduction

The ability to remember faces is crucial for social interactions. At the same time, this ability depends to a large extent on whether the observer and the perceived face belong to the same or different social groups. It has been long-known that participants are more accurate at remembering faces from their own- relative to a different ethnic group (Malpass & Kravitz, 1969; Meissner & Brigham, 2001), a phenomenon interchangeably termed the own-race bias (ORB), other-race effect or cross-race effect. More recently, a number of other, potentially related face memory biases have been discovered, including increased memory for own-age (Fulton & Bartlett, 1991; M. G. Rhodes & Anastasi, 2012; Wiese, Komes, & Schweinberger, 2013), and own-gender faces (particularly in female participants; Herlitz & Loven, 2013; Lewin & Herlitz, 2002). Moreover, participants have been reported to more accurately remember own-group faces in minimal-group paradigms, in which face stimuli are randomly assigned to the participant's or a different group on the basis of arbitrary information (such as the outcome of a fake personality test; e.g., Bernstein, Young, & Hugenberg, 2007).

Traditionally, the own-race bias has been explained by differential perceptual expertise. On the one hand, *processing* accounts suggest that specific aspects of face perception such as configural or holistic processing are more finely-tuned for own-group faces, and consequently less efficient for other-group faces (Hayward, Crookes, & Rhodes, 2013; Rossion & Michel, 2011). Less effective perceptual processing is assumed to result in less effective memory encoding and consequently less accurate memory. On the other hand, *representational* accounts suggest that the Multidimensional Face Space, a system to represent faces in memory, is shaped by experience and therefore optimized for those face categories we see more often (Valentine, 1991; Valentine, Lewis, & Hills, 2016). Of note, perceptual expertise accounts may explain not only the own-race but also the own-age bias, as it appears plausible that most people have more contact to and consequently more perceptual experience with others from their own ethnic and age groups. At the same time, expertise accounts cannot explain biases in minimal group paradigms, and an explanation of the own-gender bias is not straightforward, as most people in Western societies have similar contact to, and experience with, people of their own- and the opposite gender.

However, Herlitz and Loven (2013) have argued that the own-gender bias results from enhanced experience with female faces during early childhood, as the mother is more likely the primary caregiver in most societies. This assumed initial bias towards female faces is believed to further deepen in females by increased contact to own-gender peers later in life (who will accordingly show an own-gender bias) but counteracted by increased own-gender contact in males (who will accordingly show no gender bias). It should be noted that this explanation does not sit easily with the occasional finding of an own-gender bias in male participants (Steffens, Landmann, & Mecklenbrauker, 2013; Wolff, Kemter, Schweinberger, & Wiese, 2014; Wright & Sladden, 2003). Moreover, it remains unclear why extensive early experience with a single female face (the mother’s) should transfer to a general advantage for female faces.

Alternative to the expertise accounts, socio-cognitive explanations hold that people categorize others into social in- versus out-groups (Hugenberg, Young, Bernstein, & Sacco, 2010; Levin, 1996; Sporer, 2001), and that this categorization can be based on various facial characteristics including ethnic background, age, and gender, or even on superficial cues (e.g., background colour) signalling a randomly assigned group in a minimal group paradigm. It is further suggested that in-group faces are processed at an individual level whereas the processing of out-group faces stops at the category level. Put differently, once it is established that a particular face belongs to an out-group, this information is deemed sufficient and no further processing of individuating information is initiated (but see G. Rhodes, Lie, Ewing, Evangelista, & Tanaka, 2010). Furthermore, this difference in processing individuating information has been suggested to depend on motivation, and accordingly increasing motivation to individuate out-group faces has been reported to reduce or even eliminate face memory biases (Hugenberg, Miller, & Claypool, 2007; Hugenberg et al., 2010). It may be noted that these findings have been difficult to replicate, and that the own-race bias has been reported to have no social-motivational component in some cultural settings (Wan, Crookes, Reynolds, Irons, & McKone, 2015). In a nutshell, whereas expertise accounts assume that participants are not *able* to individuate other-group faces, socio-cognitive accounts emphasize that participants are not *motivated* to do so.

In contrast to the expertise models, socio-cognitive accounts can be applied to all of the above-described biases, and one might therefore argue that these latter approaches offer a more parsimonious explanation. Critically, this reasoning is based on the assumption that one common single mechanism underlies all biases. This, however, may not necessarily be the case. Although all biases reflect differences in memory for faces from the viewers' relative to a different group, they might still be driven by distinct underlying mechanisms. But since theoretical explanations in science aim at being parsimonious for good reason, substantial empirical evidence should be provided before the hypothesis of one mechanism driving all biases is abandoned.

As will become clear in the following paragraphs, event-related brain potentials (ERPs) provide an excellent means to search for such evidence. ERPs reflect voltage changes in the electroencephalogram (EEG) that are time-locked to a certain event. ERP components are positive and negative deflections with specific functional (e.g., sensitivity to experimental manipulations) and neuronal characteristics (e.g., latency, brain generator(s)), which have been linked to specific perceptual and cognitive sub-processes during stimulus processing. ERPs therefore may be used to examine whether different face memory biases occur at similar or different processing stages. This, in turn, can be taken as evidence for or against the assumption that the different memory biases are generated by one common mechanism.

Previous ERP research on the own-race bias has identified a number of components that differentiate between the processing of own- and other-race faces. First, the N170, a negative deflection peaking approximately 170 ms after stimulus onset (Bentin, Allison, Puce, Perez, & McCarthy, 1996), has been repeatedly found to be larger for other- relative to own-race faces (e.g., Caharel et al., 2011; Cassidy, Boutsen, Humphreys, & Quinn, 2014; Herrmann et al., 2007; Herzmann, 2016; Montalan et al., 2013; Stahl, Wiese, & Schweinberger, 2008, 2010; Walker, Silvert, Hewstone, & Nobre, 2008; Wiese, 2012, 2013; Wiese, Kaufmann, & Schweinberger, 2014). The N170 is usually assumed to reflect processes prior to the identification of individual faces, such as the detection of a face-like stimulus or structural encoding (Amihai, Deouell, & Bentin, 2011; Eimer, 2011; Schweinberger & Burton, 2003). Structural encoding is defined by Bruce and Young (1986) as the production of several descriptions of the presented face, including view-centred and more abstract descriptions of the available perceptual information. Face recognition, however, is typically considered a serial process, with recognition of individual identity being preceded by earlier perceptual processing stages (Bruce & Young, 1986, 2012). A deficit at an early stage would be carried over to later stages, and less efficient structural encoding of other-race faces may therefore also result in a deficit at processing individual identity. In line with this idea, a recent study found that the magnitude of the N170 ethnicity effect during the learning phases of a recognition memory experiment was correlated with the size of the own-race bias at test (Wiese, Kaufmann, et al., 2014).

It should be noted that a number of studies did not show a difference between own- and other-race faces in the N170 (Caldara, Rossion, Bovet, & Hauert, 2004; Caldara et al., 2003; Herzmann, Willenbockel, Tanaka, & Curran, 2011; Vizioli, Foreman, Rousselet, & Caldara, 2010; Wiese, Stahl, & Schweinberger, 2009). This inconsistency may be partly explained by different processing demands in the various experiments. More specifically, tasks that do not require participants to process faces at least at a categorical level are unlikely to yield an N170 ethnicity effect (Senholzi & Ito, 2013; Wiese, 2013).

Experiments on the own-age bias do not show larger N170 amplitudes for other-age faces. Although the N170 is typically larger for older adult relative to young adult faces, this effect is similarly observed in young and older adult participants and thus cannot contribute to own-age biases in memory performance (Komes, Schweinberger, & Wiese, 2015; Wiese, Schweinberger, & Hansen, 2008). Moreover, previous research did not yield differences in N170 amplitude during the processing of facial gender (Mouchetant-Rostaing & Giard, 2003; Mouchetant-Rostaing, Giard, Bentin, Aguera, & Pernier, 2000), or purely social in- vs. out-groups (Cassidy et al., 2014). In sum, it appears that the majority of studies suggest a larger N170 for other- as compared to own-race faces, whereas previous evidence suggests no similar effect for own- versus other-age or gender faces. These findings may therefore be seen as initial evidence for different processes underlying the different memory biases.

The N170 is typically followed by a positive-going deflection, the P2, which has been suggested to reflect the processing of metric distances between facial features (Halit, de Haan, & Johnson, 2000; Kaufmann & Schweinberger, 2012; Latinus & Taylor, 2006). Previous research has also demonstrated that P2 is larger for own- relative to other-race faces, and that this difference is absent in participants with substantial expertise with other-race faces (Stahl et al., 2008). Moreover, varying task demands during learning affects the P2 ethnicity effect (Stahl et al., 2010). Whereas the effect was clearly observed when participants were asked to categorise faces according to ethnic group, it was substantially reduced when participants were asked to rate the attractiveness of own- and other-race faces, a task that presumably required them to process all faces at an individual level. Moreover, P2 is larger for young relative to old faces, but similar to N170, this face age effect is not modulated by participant age (Wiese et al., 2008). P2 has also been reported to be more positive for female relative to male faces, but again this face gender effect did not interact with participant gender (Wolff et al., 2014). Together these findings suggest a P2 ethnicity effect, which is modulated by expertise and/or motivation to individuate, but no corresponding own-age or own-gender effects.

The negative deflection following P2, the N250, is typically regarded as reflecting individual face processing and familiar face recognition. Accordingly, N250 is more negative for celebrity versus unfamiliar faces (Andrews, Burton, Schweinberger, & Wiese, 2017; Gosling & Eimer, 2011). Moreover, immediate repetition of familiar faces results in more negative N250 amplitudes, a phenomenon known as the N250r (for a recent review, see Schweinberger & Neumann, 2016; Schweinberger, Pfütze, & Sommer, 1995), which is interpreted as reflecting facilitated access to perceptual representations of individual faces. Whereas two experiments did not detect a difference in N250r for own- versus other-race faces (Herrmann et al., 2007; Herzmann, 2016), a larger N250r for young relative to old faces has been observed in young but not older adult participants (Wiese, Kachel, & Schweinberger, 2013). Finally, in recognition memory paradigms, correctly remembered faces typically elicit larger N250 amplitudes than correctly rejected new faces. Whereas studies on the own-age bias found this N250 memory effect to be more pronounced for young faces in young adults only (Wiese, 2012; Wiese et al., 2008; Wiese, Wolff, Steffens, & Schweinberger, 2013), no corresponding effects were observed for the own-race (Wiese, Kaufmann, et al., 2014) or own-gender biases (Wolff et al., 2014). Again, these findings seem to indicate different mechanisms for the various own-group biases.

Whereas all of the above-described N250 effects, with more negative amplitudes for familiar or newly learnt faces, can be interpreted to reflect accessing either previously existing or newly-established perceptual face representations, amplitudes in this time window are also generally more negative for other- relative to own-race faces (Herzmann, 2016; Stahl et al., 2010; Wiese, Kaufmann, et al., 2014). This latter N250 ethnicity effect has been found to be statistically independent of the recognition memory effect (Wiese, Kaufmann, et al., 2014), and may therefore reflect a different process. While its exact functional role remains somewhat unclear at present, it might be related to affective processing (see Wiese, Altmann, & Schweinberger, 2014) or enhanced processing effort allocated to those faces which participants feel are more difficult (Herzmann, 2016; Wan et al., 2015).

Finally, in recognition memory experiments, correctly remembered old items elicit more positive amplitudes than correctly rejected new items at dorsal scalp sites, a phenomenon usually referred to as the old/new effect (e.g., Rugg et al., 1998). Typically, an early anterior old/new effect (approximately 300-500 ms) is distinguished from a later and more posterior effect (approximately 500-700 ms). Whereas researchers largely agree that the later effect is related to conscious recollection of study phase detail, the early effect has been interpreted as reflecting either familiarity-based recognition (MacKenzie & Donaldson, 2007; Rugg & Curran, 2007) or conceptual priming (Paller, Voss, & Boehm, 2007). Interestingly, the later old/new effect has been found to be increased for own-race (Herzmann et al., 2011; Stahl et al., 2010), own-age (Wiese, Komes, & Schweinberger, 2012; Wiese et al., 2008), own-gender (Wolff et al., 2014), and randomly assigned social in-group faces (Herzmann & Curran, 2013). Accordingly, results from the late old/new effect suggest that participants seem to remember more study phase detail when learning own-group faces, and this effect can accompany any of the various face memory biases.

In sum, the research reviewed above can be seen as accumulating evidence for separate mechanisms underlying the various face memory biases. However, different biases have been rarely studied within the same experiment (for notable exceptions, see Shriver, Young, Hugenberg, Bernstein, & Lanter, 2008; Wallis, Lipp, & Vanman, 2012; Wiese, 2012). In particular, no previous ERP study has examined the own-race and own-gender biases in a single combined study. Findings from separate experiments can in principle be related to uncontrolled differences in participant groups or stimuli, and various differences in experimental procedure complicate the direct comparison of results. Importantly, varying expertise with own- and other-group people in different settings may have a substantial effect on the outcome (see Wan et al., 2015). The present study therefore tested the own-race and own-gender biases in a combined experiment. This combination appeared particularly interesting, as, given the extensive daily-life contact to other-gender people, any effect of long-term perceptual expertise on the own-gender bias would be substantially smaller relative to the own-race bias. Given that in- versus out-group categorization should occur for both ethnic and gender groups, any residual own-race bias over and above the size of the own-gender bias in the same participants would be likely related to expertise. In addition, any finding of different neural correlates for the two effects in the same participants would substantially strengthen the idea of different processes underlying the different memory biases.

2. Methods

2.1 Participants

We tested 43 undergraduate and postgraduate students of the Friedrich Schiller University with Caucasian ethnic backgrounds. Three participants were excluded after testing, as they did not fulfil the criterion of at least 15 artifact-free trials in each condition for EEG analysis (see below). The final sample consisted of 20 female and 20 male participants with a mean age of 23 years (± 2.7 SD). All participants were right-handed according to a modified version of the Edinburgh Handedness Inventory (Oldfield, 1971) and reported normal or corrected-to-normal vision. None suffered from a neurological or psychiatric condition or took any central-acting medication. Participants either received 5€/h or course credit as a compensation. All gave written informed consent prior to the experiment and the study was approved by the local ethics committee.

2.2 Stimuli

Stimuli consisted of colour pictures depicting 200 Caucasian (i.e., central European or North American) and 200 Asian (i.e., Chinese or Korean) faces. Images were taken from the CAL/PAL face database (Minear & Park, 2004) and various other internet sources. All faces were front-facing with a neutral expression. Using Adobe Photoshop™, faces were cut out along the chin line and the outer contour of the head such that external features (ears, hair covering the forehead) were visible. Images were then pasted in front of a black background and framed within an area of 300 x 400 pixels, corresponding to a viewing angle of 6.7° x 8.9° at a distance of 90 cm. Stimuli were corrected for luminance differences by changing the mean pixel intensity of each image to a standard value of 112 (excluding the background; scale from 0 to 255).

2.3 Experimental Design and Procedure

Participants were seated in an electrically shielded, sound-attenuated and dimly lit cabin (400 A-CT-Special, Industrial Acoustics, Niederkrüchten, Germany). Their heads were placed in a chin-rest at 90 cm distance from a computer screen. Each trial started with a fixation cross (presented for 500 ms), which was followed by a face stimulus (various durations, see below), and ended with a blank screen (500 ms). Participants had to respond via left and right index finger button presses within 2000 ms after stimulus onset.

The experiment consisted of 10 blocks, each divided into a learning and a test phase. During learning, 20 faces were presented (50% Asian, 50% female) for 3000 ms each. To increase the salience of potential gender-based in- versus out-group categorization in the context of own- and other-race faces, participants were asked to decide as quickly and accurately as possible whether the current face was female or male and to additionally memorize the faces. Learning and test phases were separated by a fixed break of 30 s. During test, all faces from the directly preceding learning phase as well as 20 new faces (again 50% Asian, 50% female) were presented. Stimuli were presented for 2000 ms and in random order.

Participants were asked to decide whether the current face had been presented in the directly preceding learning phase (“old”) or whether it was new. Key assignment and allocation of stimuli to learned or new conditions were counterbalanced across participants.

Both accuracies and mean reaction times for correct responses from the learning phases were analyzed. Responses during the test phases were sorted into four categories for Asian female, Asian male, Caucasian female, and Caucasian male faces, respectively: hits (correctly remembered old faces), misses (old faces wrongly classified as new), correct rejections (CR, new faces correctly classified as new), and false alarms (new faces wrongly classified as old). Signal detection indices of sensitivity (d’) and response bias (C; see e.g., Wickens, 2002) were calculated for each of the four experimental conditions[1].

After the main experiment, all participants completed a questionnaire to estimate quantity (measured in h/week and number of contact persons) and quality of contact towards own- and other-race, as well as own- and other-gender people. This questionnaire was similar to the one used in previous studies from our group (Wiese, 2012; Wiese, Kaufmann, et al., 2014), but modified for the purposes of the present study by asking for contact to male and female own- and other-race people separately.

2.4 EEG recording and analysis

Thirty-two channel EEG was recorded using a BioSemi Active II system (BioSemi, Amsterdam, The Netherlands). Recording sites corresponded to Fz, Cz, Pz, Iz, FP1, FP2, F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T7, T8, P7, P8, F9, F10, FT9, FT10, TP9, TP10, P9, P10, PO9, PO10, I1, and I2. EEG was recorded continuously with a 512-Hz sample rate from direct current to 155 Hz. BioSemi systems work with a “zero-Ref” setup with ground and

[1] In the present context, the signal detection index of sensitivity (d’ = z[hits] – z [False Alarms]) reflects a measure of memory performance corrected for the general tendency to respond “old”, with zero indicating chance performance and increasingly positive values indicating higher sensitivity. Response bias (C = -0.5*(z[Hits]+z[False Alarms])) is a signal detection measure of the general tendency to respond “old”, independent of memory. Positive values indicate a conservative (with overall more “new” than “old” responses) and negative values a liberal response bias (with overall more “old” than “new” responses).

reference electrodes replaced by a common mode sense/driven right leg circuit (for further information, see www.biosemi.com/faq/cms&drl.htm).

Contributions of blink artifacts were corrected using BESA 5.3 (BESA GmbH, Graefelfing, Germany). EEG was segmented from -200 to 1000 ms relative to face onset, with the first 200 ms as baseline. Trials with non-ocular artifacts and saccades were rejected from further analysis using the BESA 5.3 tool with an amplitude threshold of 100 µV and a gradient criterion of 75 µV. Remaining trials were re-calculated to common average reference, digitally low-pass filtered at 40 Hz (12 dB/oct, zero-phase shift), and averaged according to the experimental conditions during learning (Asian female, Asian male, Caucasian female, Caucasian male) and test (hits and correct rejections for Asian female, Asian male, Caucasian female, Caucasian male, respectively). An inclusion criterion of a minimum of 15 artifact-free trials per condition was applied. Average number of trials per condition was 40.7 (± 5.7 SD; range: 31.2 – 46.9) for female participants and 39.9 (± 5.4 SD; range: 29.4 – 48.1) for male participants.

In the resulting waveforms, mean amplitudes for N170 (150-190 ms at P9 and P10), P2 (200-280 ms at P9/P10), and N250 (280-400 ms at P9/P10) were calculated. Moreover, at test early (300-500 ms) and late (500-700 ms) old new effects were examined at left, midline and right frontal, central and parietal channels (F3, Fz, F4, C3, Cz, C4, P3, Pz, P4). Selection of time windows was based on inspection of the grand average. Statistical analyses were performed by calculating mixed-model analyses of variance (ANOVAs), and degrees of freedom were corrected using the Greenhouse-Geisser procedure when appropriate.

Following an estimation approach in data analysis (e.g., Cumming, 2012; Fritz, Morris, & Richler, 2012), we report measures of effect size (partial eta squared, Cohen’s d) with appropriately sized confidence intervals (CIs) throughout. Cohen’s d for paired samples t-tests was bias-corrected and calculated with mean SD rather than SD of the difference as the denominator (d_{unb}) using ESCI (Cumming & Calin-Jageman, 2017). CIs on partial eta squared

(η_p^2) were calculated using scripts provided by M.J. Smithson (https://dl.dropboxusercontent.com/u/1857674/CIstuff/CI.html).

3. Results

3.1 Contact questionnaires

A mixed-model ANOVA (containing both between- and within-subject factors) on hours of contact (see Table 1) with the within-subject factors contact person's ethnicity (Asian, Caucasian) and contact person's gender (female, male), as well as the between-subjects factor participant gender (female, male) yielded a significant main effect of contact person's ethnicity, $F(1, 38) = 118.163$, $p < .001$, $\eta_p^2 = .757$, 90% CI [.627, 819], reflecting substantially more contact hours with Caucasian relative to Asian people. Moreover, a significant interaction of contact person's ethnicity x participant gender, $F(1, 38) = 4.244$, $p = .046$, $\eta_p^2 = .101$, 90% CI [.001, .259], was further qualified by a three-way interaction of contact person's ethnicity by contact person's gender by participant gender, $F(1, 38) = 9.614$, $p = .004$, $\eta_p^2 = .202$, 90% CI [.043, .368]. Post-hoc t-tests showed that female participants spent significantly more time with Caucasian females relative to Caucasian males, $t(19) = 4.874$, $p < .001$, $d_{unb} = 0.471$, 95% CI [0.236, 0.737], whereas no significant difference was detected for female versus male Asian people, $t(19) = 2.015$, $p = .058$, $d_{unb} = 0.450$, 95% CI [-.015, 0.885]. At the same time, male participants did not report a difference in time spent with female versus male people, neither for Asian, $t(19) = 1.717$, $p = .102$, $d_{unb} = 0.429$, 95% CI [-0.088, 0.971], nor for Caucasian people, $t(19) = -1.080$, $p = .294$, $d_{unb} = -0.285$, 95% CI [-0.840, 0.254].

Please note that three male participants reported substantially more contact to Asian females (30 or more h/week, with the next highest participant reporting 8 h/week) than the group mean, but that all three participants also reported substantially more contact to

Caucasian females relative to Asian females (68 vs. 34h/week, 90 vs. 30h/week, and 48 vs. 30h/week, respectively). Nevertheless, we will report statistical comparisons of the critical findings involving the male participant group both with and without these three participants. As detailed below, the most critical results (d', N170, and N250) remain unchanged when these participants are excluded.

Table 1. Contact data.

		Female Participants				Male Participants			
		Asian Fem.	Asian Male	Cauc. Fem.	Cauc. Male	Asian Fem.	Asian Male	Cauc. Fem.	Cauc. Male
Contact Hours (per week)									
	M	0.65	0.20	43.95	31.50	5.25	1.50	37.20	44.85
	SD	1.27	0.70	27.92	22.60	11.37	3.36	26.77	24.74
No. of Contact Persons (per week)									
	M	0.65	0.15	22.85	11.45	1.00	0.65	22.90	27.60
	SD	1.09	0.37	13.39	7.57	2.15	1.31	29.19	30.71
Contact Quality									
	M	0.75	0.35	3.00	2.65	0.85	0.50	2.40	2.60
	SD	1.16	0.88	0.46	0.59	1.35	0.89	0.60	0.88

Similarly, a corresponding ANOVA on the number of contact persons (see Table 2) revealed a main effect of ethnicity, $F(1, 38) = 38.776$, $p < .001$, $\eta_p^2 = .505$, 90% CI [.304, .629], with higher numbers for Caucasian than Asian people. Again, an interaction of contact person's gender by participant gender, $F(1, 38) = 15.771$, $p < .001$, $\eta_p^2 = .293$, 90% CI [.103, .453], was further qualified by a significant three-way interaction of contact person's ethnicity by contact person's gender by participant gender, $F(1, 38) = 15.748$, $p < .001$, $\eta_p^2 = .293$, 90% CI [.103, .453]. Post-hoc t-tests for female participants demonstrated higher numbers for Caucasian female relative to Caucasian male people, $t(19) = 6.772$, $p < .001$, $d_{unb} = 1.006$, 95% CI [0.593, 1.491], as well as for Asian female versus Asian male people, $t(19) = 2.517$, $p = .021$, $d_{unb} = 0.591$, 95% CI [0.091, 1.125]. Male participants did not report higher numbers of female or male contact persons, neither for Caucasian, $t(19) = -$

1.279, p = .216, d_{unb} = -0.151, 95% CI [-0.400, 0.091], nor Asian people, $t(19)$ = 1.277, p = .217, d_{unb} = 0.189, 95% CI [-0.114, 0.502].

Finally, an ANOVA on contact quality (see Table 2) yielded a significant main effect of ethnicity, $F(1, 38) = 150.745$, $p < .001$, $\eta_p^2 = .799$, 90% CI [.688, .850], with contact to Caucasian people rated as more in-depth. No additional effects were significant (all $p > .05$).

In summary, both contact quantity (in contact hours and number of contact persons per week) and quality were substantially more pronounced for own- relative to other-race people. At the same time, contact quantity to own-gender people was higher in female but not male participants.

3.2 Performance – Learning Phases

A mixed-model ANOVA on study phase accuracies (see Table 2) with the within-subject factors face ethnicity (Asian, Caucasian) and face gender (female, male), as well as the between-subjects factor participant gender (female, male) yielded a significant main effect of face ethnicity, $F(1, 38) = 9.427$, $p = .004$, $\eta_p^2 = .199$, 90% CI [.041, .365], with more accurate responses for Caucasian relative to Asian faces, as well as a significant interaction of face ethnicity by face gender, $F(1, 38) = 7.851$, $p = .008$, $\eta_p^2 = .171$, 90% CI [.027, .337]. Post-hoc t-tests revealed a trend towards more accurate responses for Caucasian male relative to Caucasian female faces, $t(39) = 1.965$, $p = 0.057$, d_{unb}= 0.36, 95% CI [-0.01, 0.75], whereas no corresponding effect was observed for Asian faces, $t(39) = 0.868$, $p = 0.391$, d_{unb} = 0.182, 95% CI [-0.606, 0.237].

Table 2. Behavioural data. RT = Reaction Time.

	Female Participants				Male Participants			
	Asian Fem.	Asian Male	Cauc. Fem.	Cauc. Male	Asian Fem.	Asian Male	Cauc. Fem.	Cauc. Male
Learning Phase - Accuracies								
M	0.95	0.95	0.96	0.97	0.97	0.95	0.96	0.98

	SD	0.05	0.09	0.03	0.06	0.03	0.03	0.03	0.03
Learning Phase - RT (ms)									
	M	813	776	788	756	971	992	951	901
	SD	224	194	222	217	200	207	178	175
Test Phase - d'									
	M	1.67	1.14	2.18	1.91	1.34	1.23	1.62	1.69
	SD	0.72	0.49	0.74	0.65	0.65	0.54	0.71	0.63
Test Phase - C									
	M	0.01	0.21	0.16	0.31	0.03	0.35	0.30	0.37
	SD	0.03	0.37	0.36	0.34	0.04	0.42	0.36	0.37

A corresponding ANOVA on study phase RTs (see Table 2) revealed significant main effects of face ethnicity, $F(1, 38) = 28.944$, $p < .001$, $\eta_p^2 = .432$, 90% CI [.226, .570], with faster responses for Caucasian than Asian faces, face gender, $F(1, 38) = 7.007$, $p = .012$, $\eta_p^2 = .156$, 90% CI [.020, .321], reflecting faster RTs for male relative to female faces, and participant gender, $F(1, 38) = 7.427$, $p = .010$, $\eta_p^2 = .163$, 90% CI [.024, .329], with faster responses for female relative male participants. Moreover, significant interactions of face ethnicity by participant gender, $F(1, 38) = 5.185$, $p = .028$, $\eta_p^2 = .120$, 90% CI [.007, .282], and face ethnicity by face gender, $F(1, 38) = 4.824$, $p = .034$, $\eta_p^2 = .113$, 90% CI [.005, .273], were further qualified by a significant three-way interaction, $F(1, 38) = 6.941$, $p = .012$, $\eta_p^2 = .154$, 90% CI [.020, .320]. Post-hoc t-tests indicated faster RTs for Caucasian male relative to Caucasian female faces in both female, $t(19) = 2.696$, $p = 0.014$, $d_{unb} = 0.136$, 95% CI [0.028, 0.253], and male participants, $t(19) = 2.733$, $p = 0.013$, $d_{unb} = 0.271$, 95% CI [0.058, 0.500]. At the same time, female participants yielded a trend towards faster responses for Asian male than Asian female faces, $t(19) = 2.082$, $p = 0.051$, $d_{unb} = 0.172$, 95% CI [-0.001, 0.354], whereas male participants did not show a corresponding effect, $t(19) = -1.188$, $p = 0.249$, $d_{unb} = -0.100$, 95% CI [-0.277, 0.072].

3.3 Performance – Test Phases

A mixed-model ANOVA on test phase d' (see Table 2 and Figure 1) yielded significant main effects of face ethnicity, $F(1, 38) = 104.733$, $p < .001$, $\eta_p^2 = .734$, 90% CI [.594, .802], reflecting more accurate memory for Caucasian relative to Asian faces, and face gender, $F(1, 38) = 11.803$, $p = .001$, $\eta_p^2 = .237$, 90% CI [.064, .402], with more accurate memory for female relative to male faces. A significant interaction of face ethnicity by participant gender, $F(1, 38) = 6.941$, $p = .012$, $\eta_p^2 = .154$, 90% CI [.020, .320], was followed-up by separate analyses for the two participant groups, and was found to reflect more accurate memory for Caucasian than Asian faces in both female participants, $F(1, 19) = 68.049$, $p < .001$, $\eta_p^2 = .782$, 90% CI [.586, .850], and male participants, $F(1, 38) = 36.798$, $p < .001$, $\eta_p^2 = .659$, 90% CI [.396, .767], but with a somewhat larger effect size in the female group. Moreover, an interaction of face gender by participant gender in the omnibus ANOVA, $F(1, 38) = 9.732$, $p = .003$, $\eta_p^2 = .204$, 90% CI [.044, .370], was followed-up separate tests for female and male participants, which revealed more accurate memory for female relative to male faces in female participants, $F(1, 19) = 13.636$, $p = .002$, $\eta_p^2 = .418$, 90% CI [.126, .596], but no corresponding difference in male participants, $F < 1$. Finally, a significant interaction of face ethnicity by face gender in the omnibus ANOVA, $F(1, 38) = 5.632$, $p = .023$, $\eta_p^2 = .129$, 90% CI [.010, .292], was followed-up by separate analyses for female and male faces, which yielded significant own-race biases for both female faces, $t(39) = 5.212$, $p < .001$, $d_{unb} = 0.522$, 95% CI [0.298, 0.762], and male faces, $t(39) = 9.461$, $p < .001$, $d_{unb} = 1.032$, 95% CI [0.730, 1.369], with a larger effect size for male faces.

When excluding the three male participants with increased contact towards Asian females, the above reported results remained unchanged, as we still detected main effects of ethnicity, $F(1, 35) = 89.727$, $p < .001$, $\eta_p^2 = .719$, 90% CI [.566, .793], and face gender, $F(1,$

35) = 12.224, p = .001, η_p^2 = .166, 90% CI [.072, .424], as well as interactions of face ethnicity by participant gender, $F(1, 35)$ = 6.169, p = .018, η_p^2 = .150, 90% CI [.015, .321], face gender by participant gender, $F(1, 35)$ = 6.960, p = .012, η_p^2 = .166, 90% CI [.021, .338], and face ethnicity by face gender, $F(1, 35)$ = 5.271, p = .028, η_p^2 = .131, 90% CI [.008, .300].

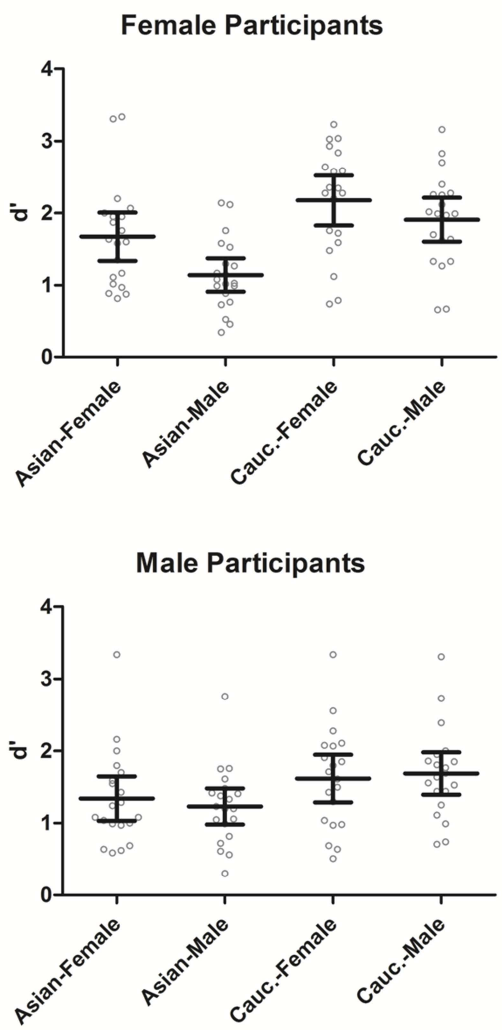

Figure 1. Mean sensitivity (d') during the test phases. Grey circles depict d' scores of individual participants, error bars the 95% CI.

A corresponding ANOVA on the response bias C (see Table 2) revealed significant main effects of ethnicity, $F(1, 38)$ = 14.422, p < .001, η_p^2 = .275, 90% CI [.089, .437], with more conservative responses for Caucasian faces, and gender, with more conservative responses for male faces, $F(1, 38) = 17.394$, $p < .001$, $\eta_p^2 = .314$, 90% CI [.119, .471]. No other significant effects were detected (all $p > .05$).

In summary, we found clear own-race biases in female and male participants and for female and male face stimuli, but with larger effects for female participants and for male faces. An own-gender bias was only observed in female participants.

3.4 Event-related potentials – Learning phases

A mixed model ANOVA with the additional within-subjects factor hemisphere (left, right) was calculated for N170 mean amplitudes (150-190 ms) at electrodes P9 and P10 (see Figure 2). This analysis yielded a significant main effect of face ethnicity, $F(1, 38) = 11.369$, $p = .002$, $\eta_p^2 = .230$, 90% CI [.059, .394], with larger N170 amplitudes for Asian than Caucasian faces (see Figure 3), which also held true when excluding the three male participants with increased contact to Asian females, $F(1, 35) = 7.805$, $p = .008$, $\eta_p^2 = .182$, 90% CI [.028, .355]. No further significant effects were observed (all $p > .05$). Importantly, none of the interactions involving face or participant gender were significant (all $F < 1$).

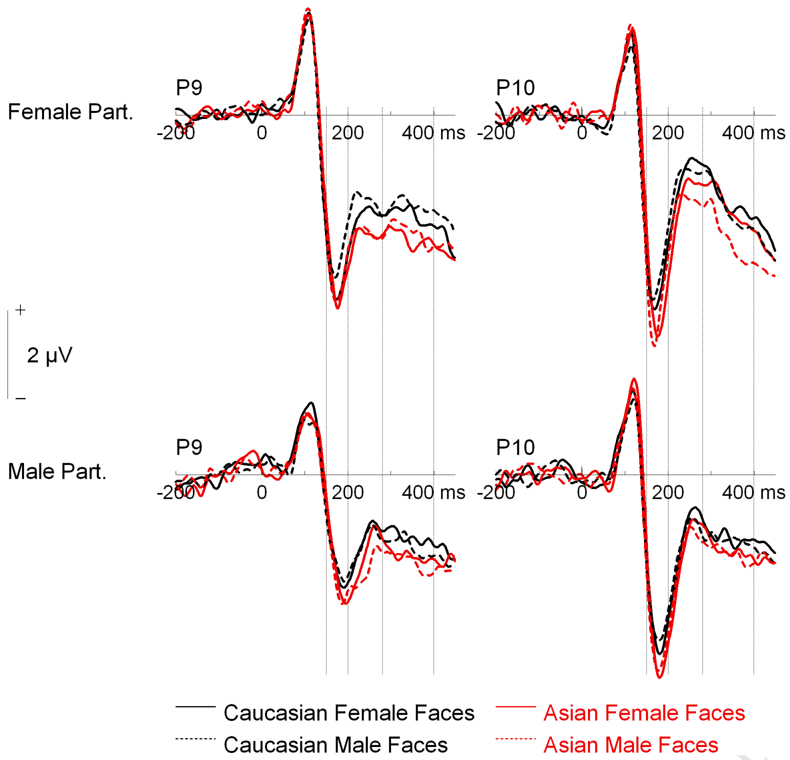

Figure 2. Learning phase grand mean ERPs at occipito-temporal channels P9/P10. Vertical lines depict the N170, P2, and N250 time windows.

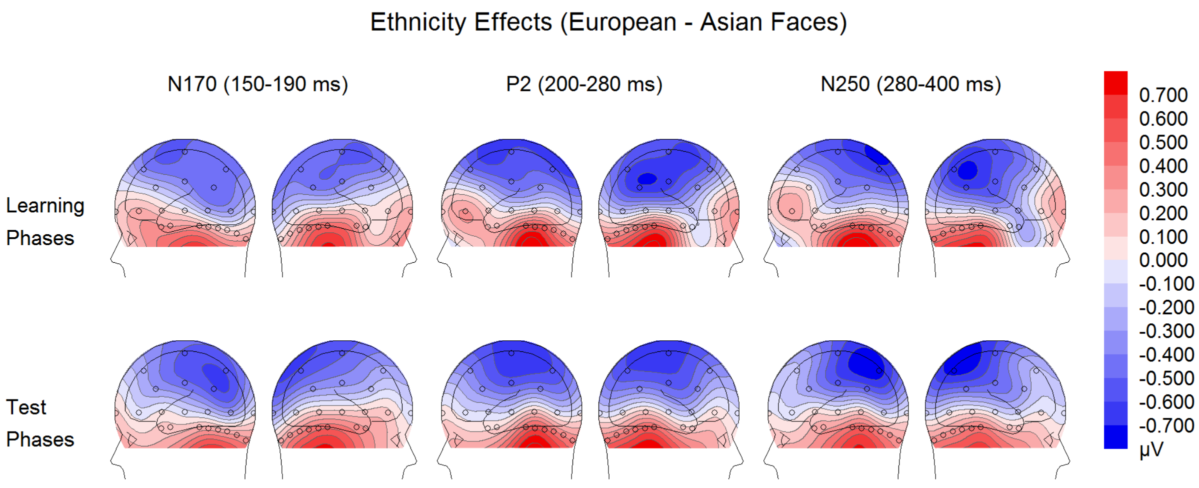

Figure 3. Scalp-topographical voltage maps (spherical spline interpolation, 90° equidistant projections) of ethnicity effects (European – Asian faces) averaged across face and participant gender during learning and test.

A corresponding analysis of P2 mean amplitudes (200-280 ms) revealed a significant main effect of face ethnicity, $F(1, 38) = 29.152$, $p < .001$, $\eta_p^2 = .434$, 90% CI [.228, .571], with larger amplitudes for Caucasian as compared to Asian faces (see Figure 3). No additional effects reached significance (all $p > .1$).

An ANOVA on N250 mean amplitudes (280-400 ms) yielded a main effect of face ethnicity, $F(1, 38) = 26.247$, $p < .001$, $\eta_p^2 = .409$, 90% CI [.203, .551], with more negative amplitudes for Asian relative to Caucasian faces (see Figure 3), as well as an interaction of hemisphere by face gender by participant gender, $F(1, 38) = 4.170$, $p = .048$, $\eta_p^2 = .099$, 90% CI [.0004, .257]. Both effects were significant when the three male participants with increased contact to Asian females were excluded; main effect of ethnicity: $F(1, 35) = 28.430$, $p < .001$, $\eta_p^2 = .448$, 90% CI [.233, .587]; interaction of hemisphere by face gender by participant gender: $F(1, 35) = 5.104$, $p = .030$, $\eta_p^2 = .127$, 90% CI [.007, .293]. Post-hoc analyses in female participants revealed significantly more negative amplitudes for male than female faces over the right, $F(1, 19) = 4.626$, $p = .045$, $\eta_p^2 = .196$, 90% CI [.003, .416], but not over the left hemisphere, $F(1, 19) = 1.054$, $p = .318$, $\eta_p^2 = .053$, 90% CI [.0, .255]. No significant difference between male and female faces was detected in male participants; left hemisphere: $F(1, 19) = 1.394$, $p = .252$, $\eta_p^2 = .068$, 90% CI [.0, 277], right hemisphere: $F < 1$.

To more directly test whether the own-race and own-gender biases rely on the same or different neural mechanisms, we compared the ERP correlates of the two effects (own- minus other-group) across the three occipito-temporal components described above (N170, P2, N250). As the analyses above revealed an own-gender bias only in female participants' N250 at right-hemispheric site P10, we focused on this group and this electrode (see Figure 4). A repeated-measures ANOVA on amplitude differences between own- and other-group faces with the factors component (N170, P2, N250) and own-group effect (own- minus other-race, own- minus other-gender) revealed a significant interaction, $F(2,39) = 3.532$, $p = .039$, η_p^2

= .157, 90% CI [.004, .302]. Post-hoc t-tests on the ethnicity effect detected no significant magnitude differences, neither when comparing N170 and P2, nor between P2 and N250, both $p > .1$. Moreover, female and male faces were not significantly different in N170 and P2, both $p > .1$, and both gender effects were very close to zero. Importantly, the gender effect was significantly larger in the N250 relative to the P2 time range, $T(19) = -3.409$, $p = .003$, Cohen's $d_{unb} = 0.391$, 95% CI [0.136, 0.670], which held true also after Bonferroni correction (with adjusted alpha = .05/4 = .0125).

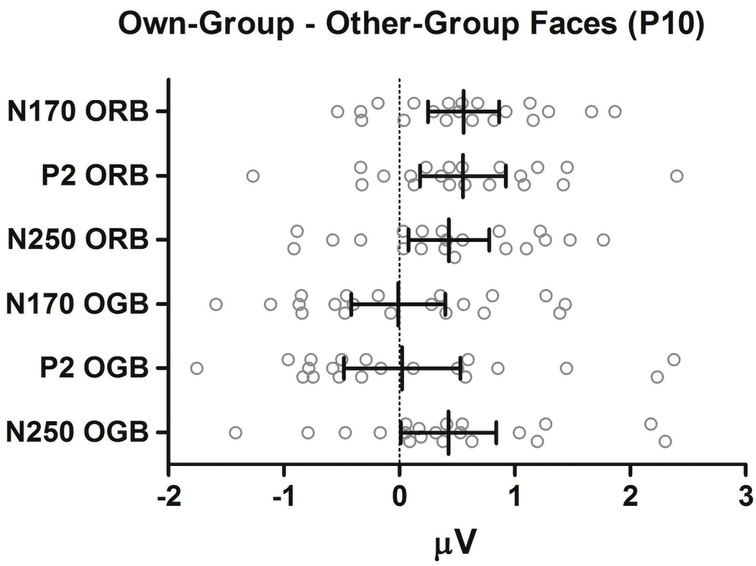

Figure 4. Female participants' own-group effects in N170, P2, and N250 at right-hemispheric electrode P10. Error bars depict 95% confidence intervals. ORB = Own-Race Bias, OGB = Own-Gender Bias.

In summary, ERPs during learning revealed larger N170 amplitudes for other- relative to own-race faces, but no difference in N170 for own- relative to other-gender faces. Moreover, larger right-hemispheric N250 amplitudes for other-gender faces were observed in female but not male participants.

3.5 Event-related potentials – Test phases

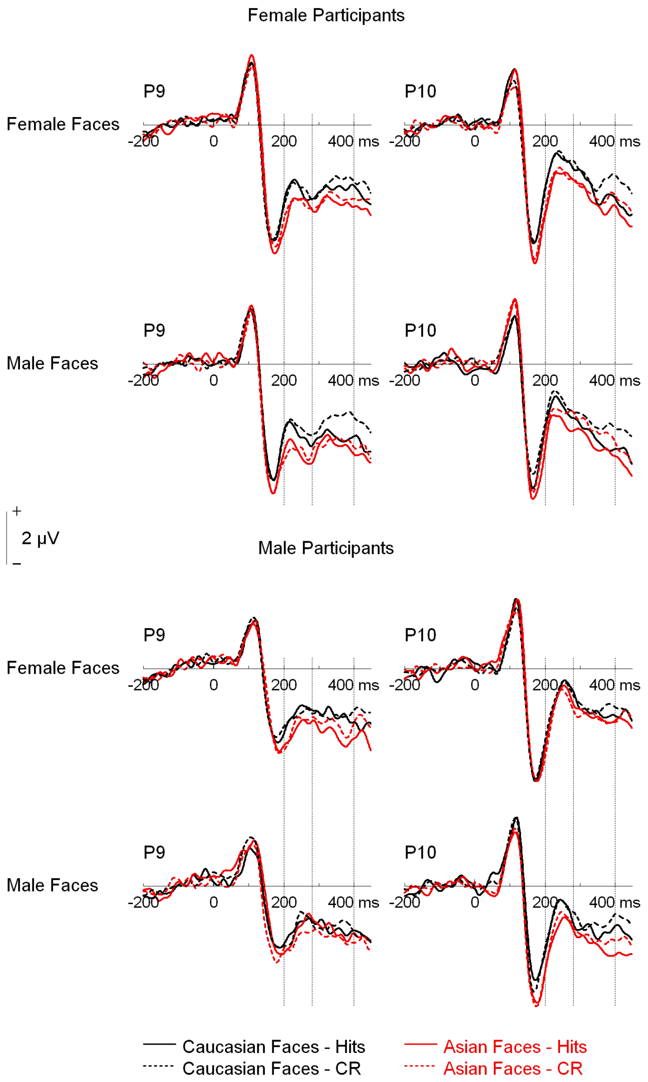

Figure 5. Test phase grand mean ERPs at occipito-temporal channels P9/P10. Vertical lines depict the N170, P2, and N250 time windows. CR = correct rejections.

A mixed-model ANOVA on N170 amplitude (see Figure 5) with the additional factor response type (hits, correct rejections) revealed a significant main effect of face ethnicity, $F(1, 38) = 30.014$, $p < .001$, $\eta_p^2 = .441$, 90% CI [.235, .577], reflecting larger amplitudes for Asian faces (Figure 3). No further effects reached significance (all $p > .05$).

A corresponding analysis on test phase P2 yielded a main effect of face ethnicity, $F(1, 38) = 42.646$, $p < .001$, $\eta_p^2 = .529$, 90% CI [.331, .646], with more positive-going amplitudes for Caucasian than Asian faces (Figure 3), which was qualified by a significant interaction of hemisphere by face ethnicity by face gender by participant gender, $F(1, 38) = 4.443$, $p = .042$, $\eta_p^2 = .105$, 90% CI [.002, .264]. Post-hoc analyses for female participants at electrode P10 demonstrated significant ethnicity effects for own-gender female, $F(1, 19) = 14.046$, $p = .001$, $\eta_p^2 = .425$, 90% CI [.132, .601], but only a trend for male faces, $F(1, 19) = 3.845$, $p = .065$, $\eta_p^2 = .168$, 90% CI [.0, 390]. At P9, significant ethnicity effects were observed for both female, $F(1, 19) = 4.443$, $p = .028$, $\eta_p^2 = .229$, 90% CI [.001, .410], and male faces, $F(1, 19) = 13.205$, $p = .002$, $\eta_p^2 = .410$, 90% CI [.121, .592], although the effect size was larger for other-gender male faces. At the same time, male participants showed significant ethnicity effects for own-gender male faces at P10, $F(1, 19) = 7.628$, $p = .012$, $\eta_p^2 = .286$, 90% CI [.039, .494], but only a trend for female faces, $F(1, 19) = 3.904$, $p = .063$, $\eta_p^2 = .170$, 90% CI [.0, 392]. At P9, male participants demonstrated a significant ethnicity effect for other-gender female faces, $F(1, 19) = 7.625$, $p = .012$, $\eta_p^2 = .287$, 90% CI [.039, .494], but only a trend for own-gender male faces, $F(1, 19) = 3.374$, $p = .082$, $\eta_p^2 = .151$, 90% CI [.0, .372]. It thus appears that P2 ethnicity effects were more pronounced for own-gender faces over the right and for other-gender faces over the left hemisphere. Follow-up tests also revealed significantly more positive going amplitudes for Asian female relative to male faces at P9, both in female participants, $F(1, 19) = 4.469$, $p = .048$, $\eta_p^2 = .190$, 90% CI [.001, .411], and male participants, $F(1, 19) = 5.475$, $p = .030$, $\eta_p^2 = .224$, 90% CI [.012, 441]. No other effects involving face gender were observed in the P2 time window (all $p > .1$).

Analysis of the N250 yielded significant main effects of response type, $F(1, 38) = 7.084$, $p = .011$, $\eta_p^2 = .157$, 90% CI [.021, .323], with more negative amplitudes for hits than correct rejections, and face ethnicity, $F(1, 38) = 29.852$, $p < .001$, $\eta_p^2 = .440$, 90% CI [.234, .576], with more negative amplitudes for other-race relative to own-race faces (Figure 3). In addition, a significant interaction of hemisphere by face gender was detected, $F(1, 38) =$

4.641, p = .038, η_p^2 = .109, 90% CI [.003, .269]. However, post-hoc tests revealed no significant differences between male and female faces, neither at P9, $F(1, 38)$ = 1.589, p = .215, η_p^2 = .039, 90% CI [.0, .175], nor at P10, $F(1, 38)$ = 2.222, p = .144, η_p^2 = .054, 90% CI [.0, .199]. No other effects were significant (all p > .05).

In the early old/new effect time window (300-500 ms; see Figure 6 and Figure 7) a mixed-model ANOVA was conducted in which the hemisphere factor was replaced by the within-subjects factors laterality (left, midline, right) and site (frontal, central, parietal). As this time window was analysed to specifically look at memory effects, the following report focuses on effects involving response type. A significant main effect of response type was detected, $F(1, 38)$ = 8.291, p = .007, η_p^2 = .179, 90% CI [.031, .345], which was qualified by a significant interaction of laterality by response type by face gender by participant gender, $F(2, 76)$ = 3.311, p = .042, η_p^2 = .080, 90% CI [.002, .175]. This latter interaction was observed as a trend when the three male participants with increased contact to Asian females were excluded, $F(2, 70)$ = 2.940, p = .059, η_p^2 = .077, 90% CI [.001, .175]. Following-up on the interaction in the complete sample, analyses (see Table 3) in female participants revealed significantly more positive amplitudes for hits relative to correct rejections over the left hemisphere for female faces and over central electrodes for male faces. Of note, the point estimate of the effect size was substantially larger for male faces. Moreover, no significant response type effects were observed in male participants. Application of Bonferroni correction for multiple comparisons (adjusted α = .05/12 = .004) revealed a significant old/new effect in female participants for male faces over central electrodes.

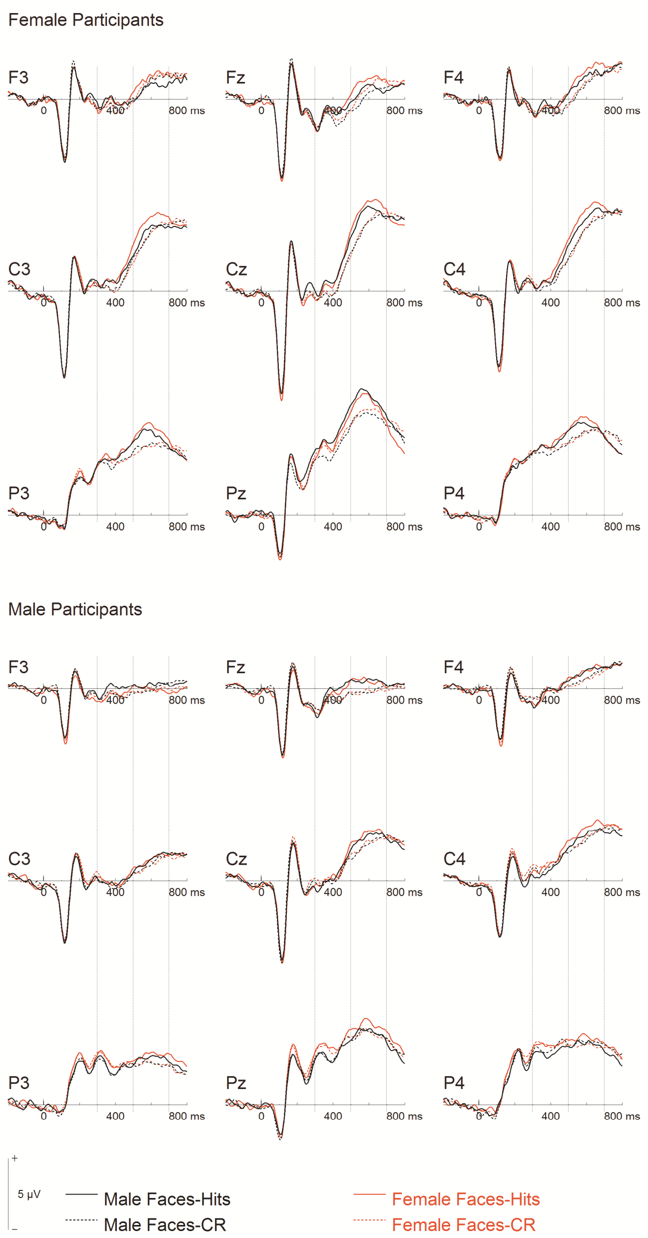

Figure 6. Test phase grand mean ERPs at frontal, central and parietal channels averaged across face ethnicity. Vertical lines depict the early and late old/new effect time windows. CR = correct rejections.

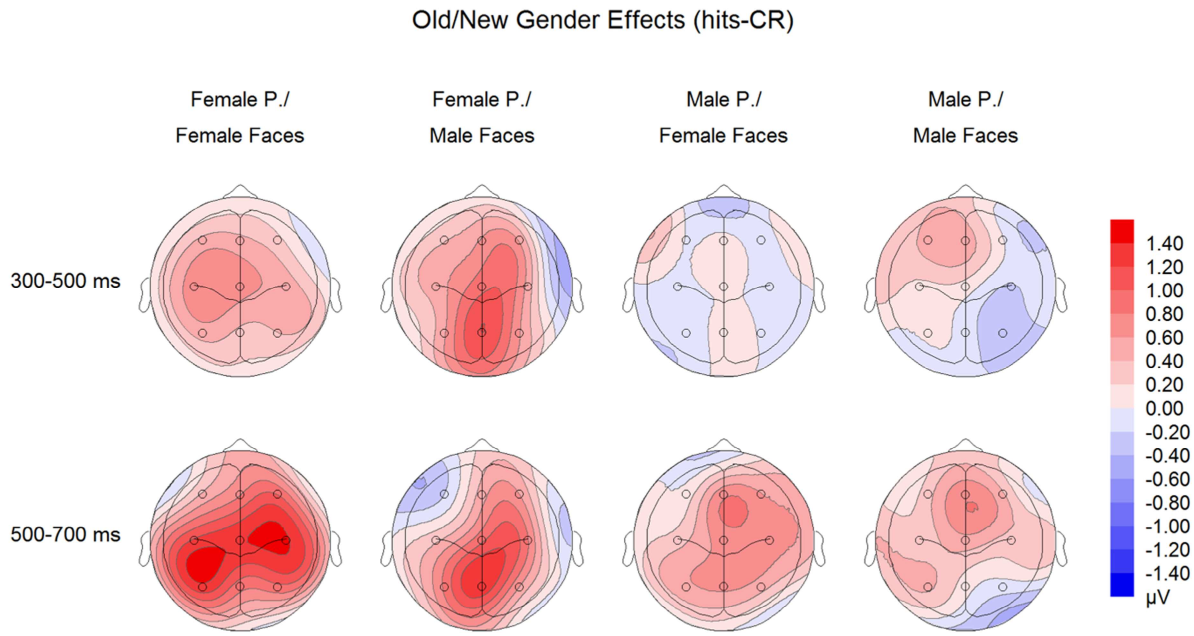

Figure 7. Scalp-topographical voltage maps (spherical spline interpolation, 90° equidistant projections) of the early (300-500 ms) and late (500-700 ms) old/new effects averaged across face ethnicity. CR = correct rejections.

Finally, a corresponding ANOVA on mean amplitudes in the later old/new effect time window (500-700 ms) again revealed a significant old/new effect, $F(1, 38) = 17.209$, $p < .001$, $\eta_p^2 = .312$, 90% CI [.117, .469], which was again qualified by an interaction of laterality by response type by face gender by participant gender, $F(2, 76) = 3.248$, $p = .049$, $\eta_p^2 = .079$, 90% CI [.001, .173]. This latter interaction did not reach significance when the three male participants with increased contact to Asian females were excluded, $F(2, 70) = 2.378$, $p = .106$, $\eta_p^2 = .064$, 90% CI [.0, .156]. Following-up on the significant interaction in the complete sample, analyses (see Table 3) in female participants yielded significant old/new effects for both female and male faces, which were substantially larger for own-gender faces. Male participants demonstrated somewhat smaller response type effects, which were again somewhat more pronounced for female faces. Application of the Bonferroni correction for multiple comparisons (adjusted $\alpha = .05/12 = .004$) revealed a significant old/new effect in female participants for female faces over right-hemispheric electrodes.

Table 3. Follow-up analyses for the early and late old/new effect time windows. Bold p-values indicate significant effects after Bonferroni-correction.

	300-500 ms			500-700 ms		
	Left	Midline	Right	Left	Midline	Right
Female Part.						
Female Faces						
F	5.021	2.792	1.808	7.154	5.214	14.664
p	.037	.111	.195	.015	.034	**.001**
η_p^2	.209	.128	.087	.274	.215	.436
90% CI	[.007, .428]	[.0, 349]	[.0, 312]	[.033, .483]	[.009, .434]	[.141, .609]
Male Faces						
F	3.503	14.056	4.438	<1	7.712	5.177
p	.077	**.001**	.049		.012	.035
η_p^2	.156	.425	.189		.289	.214
90% CI	[.0, .377]	[.132, .602]	[.001, .410]		[.040, .496]	[.009, .432]
Male Part.						
Female Faces						
F	<1	<1	<1	2.831	8.727	8.66
p				.109	.008	.008
η_p^2				.13	.315	.313
90% CI				[.0, .350]	[.054, .517]	[.053, .516]
Male Faces						
F	3.928	<1	1.216	2.798	4.408	1.017
p	.062		.284	.111	.049	.326
η_p^2	.171		.06	.128	.188	.051
90% CI	[.0, .393]		[.0, .266]	[.0, .349]	[.0003, .409]	[.0, .252]

All df = 1, 19

Overall, test phase ERP results indicated that the own-race bias was accompanied by larger N170 responses for other-race faces, reflecting differences in perceptual processing. A neural correlate of the own-gender bias was detected in the old/new effect time range, with larger early effects for other-gender and larger late effects for own-gender faces in female but not male participants.

4. Discussion

The present study examined ERP correlates of the own-race and own-gender biases in a combined experiment. Whereas both male and female participants demonstrated clear own-race biases in memory performance, an own-gender bias was only found in female participants. Moreover, ERPs revealed a larger N170 for own- relative to other-race faces, but no difference in N170 for own- versus other-gender faces. During learning, larger N250 amplitudes were observed for other-race faces in both male and female participants, whereas a respective own-gender effect in N250 was only detected in female participants. At test, larger late old/new effects for female faces in female participants paralleled the behavioural own-gender bias. As discussed in more detail below, these findings provide strong support for the idea that the own-race and own-gender biases are at least partly based on different neural and cognitive processes.

The present study revealed substantially more accurate memory for own- relative to other-race faces, replicating the standard finding of an own-race bias (Malpass & Kravitz, 1969; Meissner & Brigham, 2001). Moreover, an own-gender bias was observed in female participants only, which is in line with a recent meta-analysis (Herlitz & Loven, 2013), although some previous reports have also observed own-gender biases in male participants (Steffens et al., 2013; Wolff et al., 2014; Wright & Sladden, 2003). Interestingly, the point estimate of the own-race bias effect in females was substantially larger than the own-gender effect, even though the gender categorization task during learning arguably increased the saliency of face gender. Given that effects of perceptual expertise should be stronger in the own-race bias, whereas social categorization should occur for both ethnic and gender-related in- and out-groups, the effect size beyond the magnitude of the own-gender bias presumably reflects perceptual expertise rather than social categorization. Moreover, even the lower limit for the 90% CI suggested a large effect for the own-race bias, but not for the own-gender bias.

This suggests that the own-race bias is a more robust phenomenon, given the circumstances of the present study (see below).

Of note, the larger own-race relative to the own-gender bias is paralleled by findings from contact measures. While female participants somewhat unexpectedly reported more contact to own-gender people, this effect was substantially smaller than the difference in contact to own- versus other ethnicity people. It may thus be the case that contact affects both memory effects (for related findings, see Steffens et al., 2013). If so, it seems plausible that relatively recent daily-life contact rather than lifetime experience (as suggested by Herlitz & Loven, 2013) is relevant for the own-gender bias, which is reminiscent of similar findings for the own-age bias in older participants (Wiese et al., 2012). This suggestion is in line with the more general idea of a face representational system that is constantly updated and flexibly adapts to its environment. It should be noted, however, that previous studies have reported own-gender biases in the absence of contact differences (Wolff et al., 2014), suggesting that contact is not the only factor underlying this effect.

In line with numerous previous studies (Brebner, Krigolson, Handy, Quadflieg, & Turk, 2011; Caharel et al., 2011; Cassidy et al., 2014; He, Johnson, Dovidio, & McCarthy, 2009; Herrmann et al., 2007; Herzmann, 2016; Montalan et al., 2013; Senholzi & Ito, 2013; Stahl et al., 2008, 2010; Walker et al., 2008; Wiese, 2012, 2013; Wiese, Kaufmann, et al., 2014), N170 was larger for other-race faces in the present experiment, both during learning and at test. Of note, effect sizes were quite substantial for this effect, with even the lower limits of the 90% CIs suggesting moderate or large effects. We have argued before that the N170 ethnicity effect presumably reflects the earliest neural correlate of the own-race bias (Wiese, Kaufmann, et al., 2014). N170 is typically assumed to reflect structural encoding (e.g., Eimer, 2011), and this process seems to be more difficult for other-race faces. Importantly, it appears to reflect enhanced long-term expertise with own-race faces, as three years of intense inter-ethnic contact do not appear to be sufficient to reduce this effect (Stahl et al., 2008).

Although the N170 is typically not associated with the processing of individual identity (Eimer, 2011; Schweinberger & Burton, 2003), a deficit at an early processing stage may be carried over to later stages relevant for identity processing, given that face processing is a serial process (Bruce & Young, 1986, 2012). At the same time, the even stronger ethnicity effects in the following P2 and N250 components suggest additional processing difficulties at these later stages.

Larger P2 amplitudes for own- relative to other-race faces have been reported in a number of previous studies (Stahl et al., 2008, 2010). Recent research suggests that the face-sensitive P2 reflects the processing of second-order spatial configural information of a face relative to a mental prototype, with larger P2 amplitudes for faces with more prototypical spatial configurations (cf. Schweinberger & Neumann, 2016). In the present study, these ethnicity effects were modulated by face and participant gender, resulting in larger own-gender P2 ethnicity effects over the right and larger other-gender ethnicity effects over the left hemisphere. Of note, Stahl and colleagues (2008) observed a left-hemispheric P2 ethnicity effect in both other-race experts and control participants, whereas the right-hemispheric effect was only detected in controls. Accordingly, the modulations observed in the present results are likely not driven by expertise, as expertise for own-group faces should result in a smaller rather larger right-hemispheric P2 ethnicity effect. Alternatively, as the right occipito-temporal P2 is affected by selective attention to faces (Neumann, End, Luttmann, Schweinberger, & Wiese, 2015), attentional and/or motivational processes may modulate these effects. Independent of its exact functional interpretation, the P2 effect in the present study did not reflect the pattern observed in memory performance, as only female participants yielded an own-gender bias and both male and female participants demonstrated larger own-race biases for male faces. It is therefore unlikely that this effect contributed to the behavioural memory biases.

As evident from Figure 3, the scalp distribution of the ethnicity effects in N170, P2 and the subsequent N250 did not change substantially over time, which at first sight might suggest activity of the same generator underlying all three effects. It should be noted, however, that an *absence* of an apparent difference in distribution cannot unequivocally be interpreted as reflecting the same neural generator. Underlying generator structures may be located very close to each other in the ventral visual stream, and scalp-recorded EEG may not be able to capture such subtle differences. Moreover, previous research found that the P2 ethnicity effect is modulated by tasks that do not affect the N170 effect (Stahl et al., 2010), which suggests at least partly different processes underlying the two effects. At the same time, we cannot completely rule out that ERP ethnicity effects in the three time windows reflect one and the same underlying process in the present data, and one might speculate that such a process could reflect enhanced processing effort for the more difficult face category (Herzmann, 2016; Wan et al., 2015). One might argue that a sustained posterior negativity (e.g., Czigler & Csibra, 1990) is added to all three components and boosts those processes typically associated with N170 (face detection, structural encoding), P2 (processing of second-order configural information) and N250 (accessing perceptual representations). In conclusion, the question of whether ethnicity effects in the three time windows reflect activity of identical or different neural generators has to remain somewhat speculative, and further research is necessary to resolve it.

In contrast to the own-race bias, neural correlates of the own-gender bias manifested only subsequent to the N170. This is generally in line with previous studies that did not find clear evidence for effects of gender processing in the N170 (Mouchetant-Rostaing & Giard, 2003; Mouchetant-Rostaing et al., 2000; Wolff et al., 2014). At the same time, female but not male participants demonstrated a larger N250 for other-gender faces during learning, which is reminiscent of the ethnicity effect in this component both in the present and in previous experiments (Wiese, Kaufmann, et al., 2014). We propose that the N250 own-gender effect in females reflects differential processing of male and female faces at the level of encoding of individual identity, and may thus represent a neural correlate of more pronounced individuation of own-gender faces at learning. It should be noted, however, that our previous study on the own-gender bias (Wolff et al., 2014) did not detect a corresponding effect, and that the effect size CI in the present study indicated substantial uncertainty about the magnitude of this effect. As discussed above, our previous study also did not find differences in contact towards own- and other-gender people in female participants, and it might thus be the case that own-/other-group effects in N250 depend on differential contact. Further studies are needed to more firmly establish in which circumstances the own-gender bias is related to the N250.

In addition to effects of face ethnicity and gender, more negative amplitudes for hits relative to correct rejections were observed in the N250 time window at test. This response type effect has been observed in numerous previous face recognition memory studies, and presumably reflects access to image-dependent perceptual representations of the learnt faces. Interestingly, this effect has been observed to be larger for young faces in young but not older participants, and has therefore been suggested as a neural correlate of the own-age bias (Wiese, 2012; Wiese et al., 2008; Wiese, Wolff, et al., 2013), whereas it is similar for own- and other-race faces (Wiese, Kaufmann, et al., 2014). In line with this latter finding and with our previous experiment on the own-gender bias (Wolff et al., 2014), the present study did not detect a differential response type effect in N250 for own- versus other race or gender faces. Again, these findings indicate that different neural processes, which in turn reflect different cognitive mechanisms, accompany the various face memory biases.

In the early old/new effect time window (300-500 ms), female participants demonstrated a clear response type effect for other-gender male faces only. Such effects have been interpreted as reflecting familiarity-based recognition in previous research (Herzmann, Minor, & Adkins, 2017; MacKenzie & Donaldson, 2007). To the best of our knowledge, a finding of more pronounced ERP familiarity effects for other-group faces has not been reported before. The only previous ERP study on the own-gender bias (Wolff et al., 2014) did not examine an early old/new effect time window. However, we observed a larger early old/new effect for *own*-group faces in a combined own-race/own-age bias experiment (Wiese, 2012). The finding of enhanced familiarity for out-group faces may therefore be unique to the own-gender bias in female participants.

At some variance with previous studies (Herzmann et al., 2017; Herzmann et al., 2011; Wiese, 2012), we did not observe a larger late old/new effect (500-700 ms) for own-race faces in the present experiment. This may be related to findings suggesting that such effects depend on task requirements during learning (Stahl et al., 2010). In the present study, the gender categorization task may have substantially increased the saliency of this facial attribute, which in turn may have decreased the saliency of ethnicity information. Accordingly, a focus on gender during learning might be accountable for the absent own-race bias in the old/new effect, and may at the same time have contributed to the larger old/new effect for own-gender faces (see below). However, this interpretation is somewhat qualified by a previous experiment, which asked participants to process facial dimensions other than race (i.e., age) during learning, and still detected larger old/new effects for own-race faces (Wiese, 2012).

As noted above, and similar to our previous study (Wolff et al., 2014), we observed a larger late old/new effect for female faces in female participants. In other words, those participants who showed an own-gender bias in memory performance also demonstrated more pronounced recollection-based processing of own-gender faces. It thus seems that the enhanced sensitivity for own-gender faces (as reflected in higher d’ scores) is accompanied by the retrieval of more episodic detail from the learning episode. Larger late old/new effects have also been observed for the own-age bias (Wiese et al., 2012; Wiese et al., 2008), and the magnitude of the old/new effect for young faces has been observed to correlate with the amount of contact with this age group (Wolff, Wiese, & Schweinberger, 2012). Similarly, larger old/new effects have been observed for purely social in- versus out-group faces (Herzmann & Curran, 2013) and even for objects of particular expertise (e.g., cars and birds; Herzmann & Curran, 2011). Together, these findings suggest that enhanced recollection-based processing can accompany any recognition advantages for own- relative to other-group faces or, even more generally, for visual stimuli of particular interest. Consequently, enhanced late old/new effects do not seem to be specific for any of the face memory biases discussed here.

Taking all the above discussed findings together, the present study suggests that any theoretical account assuming a single common mechanism (e.g., in-group individuation versus out-group categorization, or more efficient holistic processing for own- versus other-group faces) as the basis for all face memory biases is likely to come up short. Neural correlates of face memory biases manifest at different processing stages, and the occurrence of the earliest ERP effect related to a particular own-group effect appears to depend on experience. Thus, in studies from our group, in which participants report quite substantial contact differences to own- versus other-ethnicity people, the own-race bias is accompanied by an N170 effect (Stahl et al., 2010; Wiese, 2012; Wiese, Kaufmann, et al., 2014). In situations in which differences in contact are smaller and less consistent (i.e., in own-age or own-gender bias experiments; Wiese et al., 2012; the present study; Wolff et al., 2014), neural correlates of own-group biases occur at later processing stages, most notably in the N250 and old/new effect time ranges. Whereas the ethnicity effect in N170 appears to reflect long-term expertise (Stahl et al., 2008), and therefore the fine-tuning of a perceptual process via lifetime visual experience, later time ranges are presumably more susceptible to variations in more recent contact and top-down influences. It therefore appears plausible to assume that they are also more likely modulated by attentional (Neumann et al., 2015) or motivational factors (as e.g. seen in larger old/new effects for purely social in-groups; Herzmann & Curran, 2013).

This line of argument also suggests that experiments on the own-race bias carried out in different circumstances, e.g., in settings with more diverse populations and participants with more long-term contact to different ethnic groups, may well find smaller own-race memory effects, a reduced or even absent influence of contact, and ERP ethnicity effects subsequent to the N170. We therefore suggest that future studies should routinely report a measure of contact to own- and other-ethnicity people.

In conclusion, the present results provide evidence for the idea that perceptual, cognitive and social/motivational processes underlie the different biases in face memory to a varying extent. More specifically, whereas the own-race bias emerges at an early structural encoding stage (N170), the own-gender bias appears to manifest at a subsequent stage of individual face processing (N250). Such findings strongly argue against the general idea that the mere existence of a specific bias (such as in- versus out-group biases in minimal-group paradigms, which cannot be explained by expertise) can inform researchers about the processes underlying memory biases in general (e.g., Bernstein et al., 2007). Specific biases in face memory occur at various stages in the cascade of processes initiated when we perceive, encode, and remember faces, and the time point of their earliest neural correlate seems to depend on how strongly they are driven by perceptual expertise and inter-group contact. We believe that future theoretical developments need to take these findings into account.

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References

Amihai, I., Deouell, L. Y., & Bentin, S. (2011). Neural adaptation is related to face repetition irrespective of identity: a reappraisal of the N170 effect. *Exp Brain Res, 209*(2), 193-204. doi:10.1007/s00221-011-2546-x

Andrews, S., Burton, A. M., Schweinberger, S. R., & Wiese, H. (2017). Event-related potentials reveal the development of stable face representations from natural variability. *Quarterly Journal of Experimental Psychology, 70*(8), 1620-1632. doi:10.1080/17470218.2016.1195851

Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience, 8*(6), 551-565. doi:10.1162/jocn.1996.8.6.551

Bernstein, M. J., Young, S. G., & Hugenberg, K. (2007). The cross-category effect - Mere social categorization is sufficient to elicit an own-group bias in face recognition. *Psychological Science, 18*(8), 706-712.

Brebner, J. L., Krigolson, O., Handy, T. C., Quadflieg, S., & Turk, D. J. (2011). The importance of skin color and facial structure in perceiving and remembering others: An electrophysiological study. *Brain Research, 1388*, 123-133. doi:Doi 10.1016/J.Brainres.2011.02.090

Bruce, V., & Young, A. (1986). Understanding Face Recognition. *British Journal of Psychology, 77*, 305-327.

Bruce, V., & Young, A. (2012). *Face Perception*. London: Psychology Press.

Caharel, S., Montalan, B., Fromager, E., Bernard, C., Lalonde, R., & Mohamed, R. (2011). Other-race and inversion effects during the structural encoding stage of face processing in a race categorization task: An event-related brain potential study. *Int J Psychophysiol, 79*, 266-271. doi:10.1016/j.ijpsycho.2010.10.018

Caldara, R., Rossion, B., Bovet, P., & Hauert, C. A. (2004). Event-related potentials and time course of the 'other-race' face classification advantage. *Neuroreport, 15*(5), 905-910.

Caldara, R., Thut, G., Servoir, P., Michel, C. M., Bovet, P., & Renault, B. (2003). Face versus non-face object perception and the 'other-race' effect: a spatio-temporal event-related potential study. *Clinical Neurophysiology, 114*(3), 515-528.

Cassidy, K. D., Boutsen, L., Humphreys, G. W., & Quinn, K. A. (2014). Ingroup categorization affects the structural encoding of other-race faces: Evidence from the N170 event-related potential. *Social Neuroscience, 9*(3), 235-248. doi:10.1080/17470919.2014.884981

Cumming, G. (2012). *Understanding the New Statistics. Effect Sizes, Confidence Intervals, and Meta-Analysis*. New York: Routledge.

Cumming, G., & Calin-Jageman, R. (2017). *Introduction to the new statistics: Estimation, Open Science, and beyond*. New York: Routledge.

Czigler, I., & Csibra, G. (1990). Event-Related Potentials in a Visual-Discrimination Task - Negative Waves Related to Detection and Attention. *Psychophysiology, 27*(6), 669-676.

Eimer, M. (2011). The face-sensitive N170 component of the event-related brain potential. In A. Calder, G. Rhodes, M. H. Johnson, & J. V. Haxby (Eds.), *The Oxford handbook of face perception* (pp. 329-344). Oxford: Oxford University Press.

Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect size estimates: current use, calculations, and interpretation. *Journal of Experimental Psychology: General, 141*, 2-18. doi:10.1037/a0024338

Fulton, A., & Bartlett, J. C. (1991). Young and Old Faces in Young and Old Heads - The Factor of Age in Face Recognition. *Psychology and Aging, 6*(4), 623-630.

Gosling, A., & Eimer, M. (2011). An event-related brain potential study of explicit face recognition. *Neuropsychologia, 49*(9), 2736-2745. doi:10.1016/j.neuropsychologia.2011.05.025

Halit, H., de Haan, M., & Johnson, M. H. (2000). Modulation of event-related potentials by prototypical and atypical faces. *Neuroreport, 11*(9), 1871-1875.

Hayward, W. G., Crookes, K., & Rhodes, G. (2013). The other-race effect: Holistic coding differences and beyond. *Visual Cognition, 21*(9-10), 1224-1247. doi:Doi 10.1080/13506285.2013.824530

He, Y., Johnson, M. K., Dovidio, J. F., & McCarthy, G. (2009). The relation between race-related implicit associations and scalp-recorded neural activity evoked by faces from different races. *Social Neuroscience, 4*(5), 426-442. doi:10.1080/17470910902949184

Herlitz, A., & Loven, J. (2013). Sex differences and the own-gender bias in face recognition: A meta-analytic review. *Visual Cognition, 21*, 1306-1336.

Herrmann, M. J., Schreppel, T., Jager, D., Koehler, S., Ehlis, A. C., & Fallgatter, A. J. (2007). The other-race effect for face perception: an event-related potential study. *Journal of Neural Transmission, 114*(7), 951-957.

Herzmann, G. (2016). Increased N250 amplitudes for other-race faces reflect more effortful processing at the individual level. *International Journal of Psychophysiology, 105*, 57-65. doi:10.1016/j.ijpsycho.2016.05.001

Herzmann, G., & Curran, T. (2011). Experts' memory: an ERP study of perceptual expertise effects on encoding and recognition. *Memory & Cognition, 39*(3), 412-432. doi:10.3758/s13421-010-0036-1

Herzmann, G., & Curran, T. (2013). Neural Correlates of the In-Group Memory Advantage on the Encoding and Recognition of Faces. *Plos One, 8*(12). doi:10.1371/journal.pone.0082797

Herzmann, G., Minor, G., & Adkins, M. (2017). Neural correlates of memory encoding and recognition for own-race and other-race faces in an associative-memory task. *Brain Research, 1655*, 194-203. doi:10.1016/j.brainres.2016.10.028

Herzmann, G., Willenbockel, V., Tanaka, J. W., & Curran, T. (2011). The neural correlates of memory encoding and recognition for own-race and other-race faces. *Neuropsychologia, 49*(11), 3103-3115. doi:10.1016/j.neuropsychologia.2011.07.019

Hugenberg, K., Miller, J., & Claypool, H. M. (2007). Categorization and individuation in the cross-race recognition deficit: Toward a solution to an insidious problem. *Journal of Experimental Social Psychology, 43*(2), 334-340. doi:10.1016/J.Jesp.2006.02.010

Hugenberg, K., Young, S. G., Bernstein, M. J., & Sacco, D. F. (2010). The Categorization-Individuation Model: An Integrative Account of the Other-Race Recognition Deficit. *Psychological Review, 117*(4), 1168-1187. doi:10.1037/A0020463

Kaufmann, J. M., & Schweinberger, S. R. (2012). The faces you remember: caricaturing shape facilitates brain processes reflecting the acquisition of new face representations. *Biol Psychol, 89*(1), 21-33. doi:10.1016/j.biopsycho.2011.08.011

Komes, J., Schweinberger, S. R., & Wiese, H. (2015). Neural correlates of cognitive aging during the perception of facial age: the role of relatively distant and local texture information. *Front Psychol, 6*, 1420. doi:10.3389/fpsyg.2015.01420

Latinus, M., & Taylor, M. J. (2006). Face processing stages: Impact of difficulty and the separation of effects. *Brain Research, 1123*, 179-187.

Levin, D. T. (1996). Classifying faces by race: The structure of face categories. *Journal of Experimental Psychology-Learning Memory and Cognition, 22*(6), 1364-1382.

Lewin, C., & Herlitz, A. (2002). Sex differences in face recognition - Women's faces make the difference. *Brain and Cognition, 50*(1), 121-128. doi:Pii S0278-2626(02)00016-7

MacKenzie, G., & Donaldson, D. I. (2007). Dissociating recollection from familiarity: Electrophysiological evidence that familiarity for faces is associated with a posterior old/new effect. *Neuroimage, 36*(2), 454-463. doi:Doi 10.1016/J.Neuroimage.2006.12.005

Malpass, R. S., & Kravitz, J. (1969). Recognition for Faces of Own and Other Race. *Journal of Personality and Social Psychology, 13*(4), 330-334.

Meissner, C. A., & Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces - A meta-analytic review. *Psychology Public Policy and Law, 7*(1), 3-35.

Minear, M., & Park, D. C. (2004). A lifespan database of adult facial stimuli. *Behavior Research Methods Instruments & Computers, 36*(4), 630-633.

Montalan, B., Veujoz, M., Boitout, A., Leleu, A., Camus, O., Lalonde, R., & Rebai, M. (2013). Investigation of effects of face rotation on race processing: an ERPs study. *Brain Cogn, 81*(3), 360-369. doi:10.1016/j.bandc.2012.12.004

Mouchetant-Rostaing, Y., & Giard, M. H. (2003). Electrophysiological correlates of age and gender perception on human faces. *Journal of Cognitive Neuroscience, 15*(6), 900-910.

Mouchetant-Rostaing, Y., Giard, M. H., Bentin, S., Aguera, P. E., & Pernier, J. (2000). Neurophysiological correlates of face gender processing in humans. *European Journal of Neuroscience, 12*(1), 303-310.

Neumann, M. F., End, A., Luttmann, S., Schweinberger, S. R., & Wiese, H. (2015). The own-age bias in face memory is unrelated to differences in attention-Evidence from event-related potentials. *Cognitive Affective & Behavioral Neuroscience, 15*(1), 180-194. doi:10.3758/S13415-014-0306-7

Oldfield, R. C. (1971). Assessment and Analysis of Handedness - Edinburgh Inventory. *Neuropsychologia, 9*(1), 97-113.

Paller, K. A., Voss, J. L., & Boehm, S. G. (2007). Validating neural correlates of familiarity. *Trends in Cognitive Sciences, 11*(6), 243-250.

Rhodes, G., Lie, H. C., Ewing, L., Evangelista, E., & Tanaka, J. W. (2010). Does Perceived Race Affect Discrimination and Recognition of Ambiguous-Race Faces? A Test of the

Sociocognitive Hypothesis. *Journal of Experimental Psychology-Learning Memory and Cognition, 36*(1), 217-223. doi:Doi 10.1037/A0017680

Rhodes, M. G., & Anastasi, J. S. (2012). The Own-Age Bias in Face Recognition: A Meta-Analytic and Theoretical Review. *Psychological Bulletin, 138*(1), 146-174. doi:10.1037/A0025750

Rossion, B., & Michel, C. (2011). An experience-based holistic account of the other-race face effect. In A. J. Calder, G. Rhodes, M. H. Johnson, & J. V. Haxby (Eds.), *The Oxford handbook of face perception* (pp. 215-243). Oxford: Oxford University Press.

Rugg, M. D., & Curran, T. (2007). Event-related potentials and recognition memory. *Trends in Cognitive Sciences, 11*(6), 251-257.

Rugg, M. D., Mark, R. E., Walla, P., Schloerscheidt, A. M., Birch, C. S., & Allan, K. (1998). Dissociation of the neural correlates of implicit and explicit memory. *Nature, 392*(6676), 595-598.

Schweinberger, S. R., & Burton, A. M. (2003). Covert recognition and the neural system for face processing. *Cortex, 39*(1), 9-30. doi:10.1016/S0010-9452(08)70071-6

Schweinberger, S. R., & Neumann, M. F. (2016). Repetition effects in human ERPs to faces. *Cortex, 80*, 141-153. doi:10.1016/j.cortex.2015.11.001

Schweinberger, S. R., Pfütze, E. M., & Sommer, W. (1995). Repetition Priming and Associative Priming of Face Recognition - Evidence from Event-Related Potentials. *Journal of Experimental Psychology-Learning Memory and Cognition, 21*(3), 722-736.

Senholzi, K. B., & Ito, T. A. (2013). Structural face encoding: how task affects the N170's sensitivity to race. *Social Cognitive and Affective Neuroscience, 8*, 937-942. doi:10.1093/scan/nss091

Shriver, E. R., Young, S. G., Hugenberg, K., Bernstein, M. J., & Lanter, J. R. (2008). Class, race, and the face: Social context modulates the cross-race effect in face recognition.

Personality and Social Psychology Bulletin, 34(2), 260-274. doi:10.1177/0146167207310455

Sporer, S. L. (2001). Recognizing faces of other ethnic groups - An integration of theories. *Psychology Public Policy and Law, 7*(1), 36-97. doi:10.1038//1076-8971.7.1.36

Stahl, J., Wiese, H., & Schweinberger, S. R. (2008). Expertise and own-race bias in face processing: An event-related potential study. *Neuroreport*, *19*(5), 583-587.

Stahl, J., Wiese, H., & Schweinberger, S. R. (2010). Learning task affects ERP-correlates of the own-race bias, but not recognition memory performance. *Neuropsychologia, 48*(7), 2027-2040. doi:10.1016/j.neuropsychologia.2010.03.024

Steffens, M. C., Landmann, S., & Mecklenbrauker, S. (2013). Participant sexual orientation matters: new evidence on the gender bias in face recognition. *Exp Psychol, 60*(5), 362-367. doi:10.1027/1618-3169/a000209

Valentine, T. (1991). A unified account of the effects of distinctiveness, inversion, and race in face recognition. *The Quarterly Journal of Experimental Psychology, 43A*, 161-204.

Valentine, T., Lewis, M. B., & Hills, P. J. (2016). Face-space: A unifying concept in face recognition research. *Quarterly Journal of Experimental Psychology, 69*, 1996-2019. doi:10.1080/17470218.2014.990392

Vizioli, L., Foreman, K., Rousselet, G. A., & Caldara, R. (2010). Inverting faces elicits sensitivity to race on the N170 component: A cross-cultural study. *Journal of Vision, 10*(1), 1-23. doi:10.1167/10.1.15

Walker, P. M., Silvert, L., Hewstone, M., & Nobre, A. C. (2008). Social contact and other-race face processing in the human brain. *Social Cognitive and Affective Neuroscience, 3*(1), 16-25.

Wallis, J., Lipp, O. V., & Vanman, E. J. (2012). Face age and sex modulate the other-race effect in face recognition. *Atten Percept Psychophys, 74*(8), 1712-1721. doi:10.3758/s13414-012-0359-z

Wan, L. L., Crookes, K., Reynolds, K. J., Irons, J. L., & McKone, E. (2015). A cultural setting where the other-race effect on face recognition has no social-motivational component and derives entirely from lifetime perceptual experience. *Cognition, 144*, 91-115. doi:10.1016/j.cognition.2015.07.011

Wickens, T. D. (2002). *Elementary signal detection theory*. Oxford: Oxford University Press.

Wiese, H. (2012). The role of age and ethnic group in face recognition memory: ERP evidence from a combined own-age and own-race bias study. *Biological Psychology, 89*, 137-147. doi:10.1016/j.biopsycho.2011.10.002

Wiese, H. (2013). Do neural correlates of face expertise vary with task demands? Event-related potential correlates of own- and other-race face inversion. *Frontiers in Human Neuroscience, 7*. doi:10.3389/Fnhum.2013.00898

Wiese, H., Altmann, C. S., & Schweinberger, S. R. (2014). Effects of attractiveness on face memory separated from distinctiveness: evidence from event-related brain potentials. *Neuropsychologia*, *56*, 26-36. doi:10.1016/j.neuropsychologia.2013.12.023

Wiese, H., Kachel, U., & Schweinberger, S. R. (2013). Holistic face processing of own- and other-age faces in young and older adults: ERP evidence from the composite face task. *Neuroimage, 74*, 306-317. doi:10.1016/J.Neuroimage.2013.02.051

Wiese, H., Kaufmann, J. M., & Schweinberger, S. R. (2014). The neural signature of the own-race bias: Evidence from event-related potentials. *Cerebral Cortex, 24*, 826-835. doi:10.1093/cercor/bhs369

Wiese, H., Komes, J., & Schweinberger, S. R. (2012). Daily-life contact affects the own-age bias and neural correlates of face memory in elderly participants. *Neuropsychologia, 50*, 3496-3508. doi:10.1016/j.neuropsychologia.2012.09.022

Wiese, H., Komes, J., & Schweinberger, S. R. (2013). Ageing faces in ageing minds: a review on the own-age bias in face recognition. *Visual Cognition, 21*(9-10), 1337-1367. doi:10.1080/13506285.2013.823139

Wiese, H., Schweinberger, S. R., & Hansen, K. (2008). The age of the beholder: ERP evidence of an own-age bias in face memory. *Neuropsychologia, 46*(12), 2973-2985. doi:10.1016/j.neuropsychologia.2008.06.007

Wiese, H., Stahl, J., & Schweinberger, S. R. (2009). Configural processing of other-race faces is delayed but not decreased. *Biological Psychology, 81*(2), 103-109. doi:10.1016/J.Biopsycho.2009.03.002

Wiese, H., Wolff, N., Steffens, M. C., & Schweinberger, S. R. (2013). How experience shapes memory for faces: An event-related potential study on the own-age bias. *Biological Psychology, 94*, 369-379. doi:10.1016/j.biopsycho.2013.07.001

Wolff, N., Kemter, K., Schweinberger, S. R., & Wiese, H. (2014). What drives social in-group biases in face recognition memory? ERP evidence from the own-gender bias. *Soc Cogn Affect Neurosci, 9*(5), 580-590. doi:10.1093/scan/nst024

Wolff, N., Wiese, H., & Schweinberger, S. R. (2012). Face recognition memory across the adult lifespan: ERP evidence from the own-age bias. *Psychology and Aging, 27*(4), 1066-1081. doi:10.1037/a0029112

Wright, D. B., & Sladden, B. (2003). An own gender bias and the importance of hair in face recognition. *Acta Psychologica, 114*(1), 101-114. doi:Doi 10.1016/S0001-6918(03)00052-0